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With kind regards
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The Predisposition of Plants to Parasitic Diseases.

BY

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THE PREDISPOSITION OF PLANTS TO PARASITIC DISEASES.

By H. T. Güssow, F.R.M.S.,
London Botanical Laboratory.

At present we are accustomed to characterise fungi as saprophytes and parasites, and it is necessary to give a brief definition of these terms here, before dealing with my main subject which cannot be too distinctly emphasised, namely, the relation of them to diseases of plants.

A fungus is parasitic when it takes its food from the cells of living plants entirely, growing in and destroying living cell tissues on its way.

On the other hand, it is saprophytic when it does not enter living cells, but takes its food from the dead and dying protoplasm, and passes through its whole cycle of life in decaying tissues.

From the beginning, according to the present state of affairs, saprophytes are almost at once excluded from consideration as regards causing disease, and it remains now for us only to consider parasites and their relation to disease. I wish, however, to point out, and hope to prove in the following lines that these characters given to the fungi are far too precise. For it is well known that under certain circumstances parasites live as saprophytes and vice-versa. Where then does the parasitism of a fungus begin and where saprophytism? Would it not be wiser and more cautious for phytopathologists, regarding the frequent changes of fungi from the saprophytic to the parasitic mode of life, to avoid characterising them in that manner and adopt some method of more uniformly dealing with fungi as a whole? I am well aware that I am putting forth in these sentences nothing but hypotheses, but let us give to all fungi equal attention, and not in plant pathology exclude from the first those which we know, *i.e.*, which some observers have recorded as purely saprophytic.

I will go still further. It is well known that almost every fungus, whether parasitic or saprophytic, can artificially be cultivated on certain culture media. Why is it that such a recognised strong parasite as *Phytophthora* can be made to grow on the same medium under the same conditions of temperature, moisture, etc., as, for instance, one of our commonest moulds, *Mucor*, which has never been known to grow on living tissues? There are the same conditions of culture, and one grows as well as the other! Let us give a still more crude example. The condition of the medium, of the nidus alone, accounts highly for the possibility of the development of a fungus. No one would expect a fungus to grow upon the raw culture material without the necessary moisture. This consequently establishes one factor necessary for the growth of fungi, viz., a given amount of moisture. Without which no fungus will develop.

Everyone knows the manufacture of dried milk. In the dry condition the milk is correctly certified to be perfectly immune of pathogenic and other microbes. When a dish containing the dried milk is placed on a moist sheet of blotting paper under a glass globe for about 12 hours, sufficient moisture is absorbed to still keep the milk in a semifirm condition, but to give a sufficient supply of moisture to induce the growth of bacteria and scores of fungi when the milk is subsequently exposed to the air. On the other hand, a favourite nidus for the cultivation of fungi is potato. Even when thickly sown on slices of a freshly-cut raw potato, where plenty of moisture is present, no fungus will grow. The reason lies quite near to hand. The tissues of the raw potato are not suited, and sufficient resistance is exercised to prevent the development of any fungus. But on removing that capacity of the potato by boiling or dipping it into a 2% solution of Sublimat, washing it, and repeating the sowing, fungi will at once grow. Apply these simple experiments to the relation of a fungus to living tissues of a plant. Do not our infection experiments more or less prove the existence of the power of resistance offered by a host plant?

E. Salmon quite recently read a paper before the Royal Society proving that the mycelium of *Erysiphe* grows between the cells in the leaf of grasses. But to infect the leaves he records that it was necessary to slightly abrade the epidermis to enable the hyphae to grow within the tissues. Sowing the spores on an uninjured surface causes no development of the fungus whatever. The protecting cells of the stomates, under healthy conditions, are stronger than the power of the fungus to force through them in the ordinary way. I am quite aware that *Erysiphe* has been seen, and that by myself, growing on apparently uninjured surfaces of grasses, but is it not likely that within a plant certain predisposing conditions may have set in, weakening the power of resistance, similarly as the abrasion of the epidermis in the above experiment, has overcome the power of resisting attacks of fungi?

I received some time ago specimens of wheat badly attacked by *Cladosporium herbarum.* The fungus was present in all attacked portions, and the mycelium was growing freely in the tissues. I failed in every experimental infection of healthy wheat plants and went on to some more drastic measures. Several plants about six inches high were placed under a glass globe and half the plants selected for infection. Over portions of the leaves of these plants, a glowing glass rod was held, not sufficiently near to char the epidermis, though near enough to slightly discolour the surface; then I moistened all plants equally and distributed over all of them as evenly as possible the spores of *Cladosporium.* The glass globe then once more covered the healthy and impaired plants. After twelve days I found *Cladosporium* growth everywhere where the leaf portions had come into close proximity with the glass rod; the other portions were healthy. I watched the plants for several weeks and found that as soon as the *Cladosporium* had filled the whole of the injured area the leaves were dry in these portions, whilst the neighbouring tissues remained healthy, and so did the other plants and newly-developed leaves. Professor Sorauer has established these same facts by the same experiment. (12. Jahresbericht für Pflanzenschutz, 1902, p. 205). These few cases plainly show that the fungus does not grow on perfectly healthy plants, but readily on artificially injured ones. Hence it is obvious to regard the condition of a host plant as a necessary factor for the effectual attack of a fungus. The experiments further show that an alteration of the natural condition favoured the growth of the fungus, whilst the maintenance of the same proved unsuitable to its development. Does not this at the same time account for the failure of so many infection experiments of living tissues, because the experimentor has failed to produce a certain susceptibility within the host plant? Undoubtedly the constitution in a plant, to adopt the term from human pathology, accounts largely for the development of a fungus.

The late Professor H. M. Ward, in the Croonian lecture read before the Royal Society, February 27, 1890 (see Proc. Roy. Soc., vol. xlvii., p. 418), expressed himself on the subject:— " . . . . in some of its deviations from the normal, the plant offers conditions to an attacking parasite which may be at one time favourable, at another not." Another notice illustrating our subject I quote from the same author's book, "Diseases in Plants," 1901, pp. 93-94: "A plant in perfect health and in the fullest exercise of all its functions, has its roots in a soil which is suitably warmed and aerated, contains the right quantities of water which dissolve just the proper proportions of all essential mineral salts, but nothing poisonous, while the soil itself has a texture such that the roots and root hairs can extend and do their utmost in absorbing" . . . . . (And p. 95.) "Now suppose the same plant, with its roots in an unsuitable soil, too dry or too poor in mineral supplies, for instance". . . . . "the supplies now coming to the cambium are diminished since the want of water and minerals compels the leaves to put aside any excess of carbohydrates and the plastic materials, which do pass to the cambium so deficient in water cannot be directly utilised, and a starvation period sets in."

Let us now consider some items from human pathology. In the latter study greatest stress is being laid upon the individual. Proceeding from the view that what is good for one may prove fatal to the other, medical advisers to insurance companies carefully question an applicant as to the cause of death of his parents and grandparents, with the view of ascertaining if any predisposition exists to certain diseases, and reject or "load" any candidate who may prove thus predisposed, though at present enjoying the best of health. This sometimes seems hard upon a candidate, but if one only goes over the records, one can see most disastrous effects in the chronicles of such companies. Then there is the question of infection. In the cholera epidemic at Hamburg some ten years ago, many people became infected as soon as they came into contact with a patient. Medical men, however, save in a few exceptional cases, remained healthy. With the proper care the bacillus does not necessarily cause injury. The poorer classes in big epidemics as, for instance, the present outbreak of cerebral meningitis in Germany and America plainly shows, succumb first to the disease, not necessarily because they are constitutionally more predisposed than others, but most probably their surroundings proved more favourable to the development of the disease. But even in quarters where the disease was most prevalent, one member of a family remained healthy, whilst all others succumbed, even though he was in constant touch with them. There we have a complete immunity from disease which often can be observed in plant life. This property is presumably inherent either in the resistive power of an individual organism or in accidental circumstances. In human pathology no one will doubt the existence of individual susceptibility or immunity; why should an exception be made in plant pathology? The mortality amongst infants is recognised to be only a question of nourishment. A child reared properly, will certainly have more resistive power in itself than a child reared carelessly. The greatest stress is laid in medicine upon the origin of disease, so we find an interesting note in the "Address in Medicine," delivered at the 73rd annual meeting of the British Medical Association, by Henry Maudsley, M.D., F.R.C.P. ("British Medical Journal," July 29, 1905, p. 227): "Looking out on the present state and prospect of medicine, it is obvious that its future work will be mainly to prevent and stop the beginnings of disease" . . . . "by all fit measures and precautions to defend it from those attacks that come from without, whether in gross form or as invisible microbes." . . . And: " . . . . The second aim of preventive treatment—thrown into the background by the eager quest of the microbe—is to obviate the predisposition or tendencies to disease which lie within the organism."

That raises the question—where does disease begin? A patient with measles, during the time of incubation, rarely shows the slightest symptom of that disease. Certainly the disease does not begin with the recognition of its symptoms. Many instances in medical science prove this as a fact. When one is able to recognise the symptoms of the disease, one has not by a long way found its origin.

But how do phytopathologists deal with a plant disease? Are not often quite secondary fungi blamed as having caused the disease? No fungus or bacterium can be detected, though the plant is plainly diseased. In that case suspicion arises as to the cause of such disease, in which no irritant is detected. Of course annual plants die off, after their seeds have ripened, but this may fairly be regarded rather as a natural process of passing into a new cycle, than as a true death; the old former type of plant survives in the seed and will spring forth again. On the other hand plants rarely die from exhaustion or old age. Always definite conditions, I must maintain, are responsible for the death of any organic being. These conditions in plant life may be of various kinds. Conditions of weather and culture, superabundance or deficiency of water, air, light, chemical constituents in the soil, etc., etc.; all these factors have been known to end the life of plants. Though the conditions are probably natural, they can be injurious. Consequently the phytopathologist must direct his greatest attention to the injurious factors in plant life. Clearly opposed to this theory is the health theory. Maintain the normal conditions necessary for the life of a plant, keep the plant free from abnormal changes, and health is established.

The study of the abnormal conditions should begin with those brought about by Nature. Even plants indigenous to a locality may suffer more or less through climatic changes—frost, heat, drought, etc. The injuries of plants by frost are well known; the succulent tissues freeze and burst their cell membranes, and a more or less severe injury is recognisable. Heat and drought are closely allied, and injuries to crops in years when both are prevalent, may prove very disastrous. These are natural conditions, though at the same time injurious to the vegetation. Other injuries are brought about by impure air, smoke poisoning, unsuitable nature of the soil, errors in manuring, etc. These unnatural conditions prove still more injurious to vegetation. That death is due in many cases to the above-mentioned factors is established, but it is also proved that, short of being killed, plants may merely suffer by such causes, and go on growing, but with a increased tendency to take disease. Being no longer in a state of health, little is necessary to end their period of life. Mechanical injuries, accidental injuries by man or animal, storm and lightning, may impair the health of a plant. Plants are highly sensitive, some showing this property more than others. *Mimosa pudica, Abrus precatorius, Acacia lophanta, Gleditschia, Robinia, Trifolium*, and scores of other plants exhibit extremely sensitive characters. These so plainly exhibit this character, that it can be seen by the untrained observer. Others again show exactly the same reactions, but only visible to the physiologist. How easily also can such beings be influenced so that they may suffer and become susceptible. Physiologists have proved great changes by frost internally, where externally health was apparently preserved. Here is the field for the careful investigator. The symptoms must be taken into account less than the primary cause of the injury. The necessity of this statement needs to be proved by a few examples.

In mycology it is well-known that many fungi attack plants in certain stages of development only. The results of my own researches, and other writers, puts it beyond doubt that young and tender leaves, buds, twigs, and whole plants are more readily attacked than old and hardy ones. In forcing plants for the market they are grown under extremely unsuitable conditions, and large and soft leaves develop, easily falling a prey to many fungi which would not succeed in attacking plants grown under ordinary condi tions. Let us recall the great havoc amongst cucumbers grown in hot houses, by the "cucumber spot disease," a fungus called *Corynespora Mazei* (see "Journal Royal Agricultural Society," 1904, p. 270-272.) This fungus is only observed on cucumbers grown in hot houses. Considering the atmosphere prevailing in these houses and the wholly unnatural conditions under which the plants are cultivated, one can easily understand the rapidity with which the disease spreads. If given a heavy supply of manure large hypertrophic leaves develop, with a thin epidermis, succulent and flaccid from the beginning. It is therefore no wonder that the fungus readily attacks and speedily kills the whole of the plants. But considering the fact that the fungus has never been observed on cucumber plants grown outdoors, must not one hold the conditions prevailing in the hot houses responsible? The plants are less resistant, the growth of the fungus is encouraged by the excessive heat and moisture present and want of ventilation. My experiments in infecting healthy cucumber plants outdoors have never succeeded, whilst a simple coating on the leaves indoors with the spores of *Corynespora*, at once produced the characteristic spots on the leaves.

Another example illustrating the pronounced susceptibility of plants forced in houses or frames, is afforded by *Peronospora Lactucae*, which attacks the lettuce plants grown under glass, whilst those growing out of doors never suffer from the fungus.

Sudden changes of temperature often have as a consequence immediate outbreaks of diseases. The practical gardeners assure us that on opening the doors and windows of a rose house for a short time only, mildew will at once appear. The plants become more susceptible owing to the chill, and the fungus spores, undoubtedly present in the house before, germinate, and grow on the leaves.

I undertook some years ago a simple experiment, which plainly shows the influence of cultural conditions on the development of plants. Two small boxes, filled with the same soil, were sown with cress. Box "1" received a very strong sowing, whilst box "2" a light one. The boxes were exposed to the same conditions, and the seeds came up at the same time. The plants received the equal quantity of water, but I noticed that the water took longer to evaporate in the box with the heavier sowing, being held by the closeness of the plants. One morning, six days after sowing, I detected a small patch of dying plants in the box which received the heavy sowing, and I at once removed the other box to another place in the same house.

fearing an infection. Though I removed the diseased plants and their neighbours from the box, in a few days all the plants had succumbed to the ravages of the fungus, *Pythium* de Baryanum, Hesse. The plants in box "2" were healthy. For a check I had placed outside the house two boxes sown in the same manner; they showed from the beginning much stronger short and dark green plants, and remained healthy throughout.

Now let us briefly consider the influence of the chemical and mechanical condition of the soil on the growth of the plants. The best examples for the former are supplied by manurial experiments. The right proportion of the ingredients, necessary for the development of plants, present in the soil, are readily utilised, and the plants, providing all other predisposing factors are absent, will grow normally. If these ingredients are absent, or by errors in manuring too abundantly present, the result will either be starvation or over-nutrition, the plants showing feeble or no growth at all.

A striking observation on the mechanical condition of the soil I made some time ago in Lancashire. I was struck by the presence of large quantities of stones in the fields, which caused great annoyance to the farmers in the district. One farmer who had carted them off the field, had to cart them back as his crop came to nothing on the field from which the stones were removed, whilst a normal growth of the same kind of wheat in his neighbouring fields was noticeable. The year was a dry one, and the relation of the moisture in the two fields was remarkable. Rust had badly attacked the plants in the field without the stones, whilst little was observed in the other fields. That the intensity of an attack of rust depends largely on the resistive power of the host plant is certain, and also referred to in a sentence by Prof. Sorauer, in the 14. Jahresbericht für Pflanzenschutz, pp. 264-265, saying:—" . . . . The experience that rust attacks do not show themselves always with the same intensity depends on the resistive power of the host plant. All observations point in the direction that a condition of weakness must be present for the development of the fungus into an epidemic. We are not yet in a position to precisely establish the factors of such condition of weakness, but we learn from already existing observations under what circumstances such weakening conditions of cereals can be brought about. As indications of them we can name in many cases the yellowish discolouration of the points of the leaves which are very distinctly observed after frost or sudden change of temperature, superabundance or deficiency of water, or even the too sheltered position of the field. These factors probably cause a disturbance in the power of assimilation, under which the plants experience a slackening or temporary stop. . . . " If light and moisture and necessary summer heat enable the plant to grow quickly and luxuriantly, the rust is arrested in its progress, or, as some writers express it, "the plant outgrows the rust."

Numerous observations show an improvement or restoration of the constitution of the plants by mechanical means, if they have grown to such a depth that the roots have reached impenetrable clay or rocks. In an orchard growing on London clay, with about four feet of suitable top soil, young apple and pear trees were planted, and throve well, till suddenly, one year, a remarkable change became noticeable. The leaves fell earlier than usual, and the quality of the fruit was much impaired, though they ripened. Heavy manuring was carried out in the next few years, with some slight improvement, but after a short period the trees were in as bad a state as ever. When digging up the trees it was found that the roots had reached a thick bed of clay and could not penetrate it. In consequence no food was absorbed, and the trees suffered from starvation. The fruits were much blemished with pear and apple scab. The owner then had all the trees lifted, the roots cut, the ground ploughed, and the trees replanted. In a year or two the trees had outgrown their disturbance and bore fruit as good as ever.

A very similar case in cultivation of grapes came under my observation recently. I received in the first instance some grapes which were very shrivelled in appearance. Several fungi like *Cladosporium*, *Botrytis*, *Aspergillus*, and a *Tubercularia* were present, but were not the cause of the condition of the grapes. I ascertained that the vines were old plants, too heavily cropped, and the roots had grown too low to benefit from the usual top-dressing as practised in vine borders. In another nursery exactly the same occurred, the grapes shrivelled and various fungi grew on them. The gardener lifted the vines and replanted them near the surface, and now has a healthy crop. In this case of what use would spraying with fungicides have been? *Cladosporium viticolum*, *Botrytis cinerea*, etc., have been reported as serious pests in grape culture, but here they were the result and not the cause of the malady.

Some examples from the territory of forestry are worth recording. Some months ago—in February—I received at the laboratory a young larch tree, being one of a large number which had died from some cause or other. The tree was about twelve years old, and had failed in health the year before, and died the year it was sent to me. On investigation I failed to discover the presence of any fungus, bacterium, or external injury on the part above the ground. The main root, however, was dead, and an injury manifesting itself by the discolouration of the bark, the cambial layer and the woody tissues, could be traced from the root upwards to the main stem about a foot above the ground. Even in the decayed tissues no mycelium was present, though the injury was plainly marked. Having thus ascertained the seat of the injury, I found that the decay of the root was by no means a rare occurrence in larch trees. A wet rot of larch trees caused by bad drainage had been investigated previously, and as the symptoms of the tree agreed with those subject to recent investigation, and those recorded by other writers, I came to the conclusion that the larches had grown under unsuitable conditions. To further investigate the cause I paid a visit to the plantation to ascertain if my theory could be confirmed on the spot. In April I visited the plantation. The forester in charge informed me that the trees on the whole made a satisfactory growth in the first year only, though even then some were noticed to make better progress than others. A few had not taken at all in the ground. The plantation was situated on the slope of a hill and extended about fifteen yards into the flat bottom of a small valley. The hill side, opposite to the larch plantation, was planted with a mixed assortment of shrubs and trees as *Corylus*, *Fraxinus*, *Fagus*, etc. The larch trees in the bottom of the valley showed plainly a stunted unsatisfactory growth, and were in a dying state everywhere. Alongside the plantation ran a covered drain, which had fallen in, and was of no service whatever. The foliage of the trees had not then developed, but it was not difficult to discover the dead and dying trees by the shrivelled appearance of the bark. On all the dead and dying trees in the valley the larch canker fungus was present, but none on the trees on the slope of the hill, which were quite healthy. On examination the soil was found very unsuitable for the growth of the larch. It consisted of a clayey limestone compound, and was wet and cold. The water coming from the top of the hills collected at the bottom of the valley, and could not flow off on account of the imperfect drain. I found no canker fungus on perfectly healthy trees, though some of these showed plain mechanical injuries and wounds, supposed to be so necessary for the attack of this fungus. On the contrary I found some branches of the dead trees covered with the fruits of the fungus extending in between still healthy trees, but no attack of the fungus on the healthy trees was observed. We plainly learn from this experience that the *Dasyscypha willkommii* is by no means a strict parasite, making use of decaying tissues. But I am not alone in this view, A. Cieslar in "Centralblatt für das gesammte Forstwesen," 1904, 27 pp., says: " . . . . A larch growing luxuriant, under suitable conditions, suffers no damage from the fungus [*Dasyscypha*], even if certain conditions favouring the growth of the fungus are present. The degree of the damage by canker fungus depends largely on unsuitable conditions under which the larch is grown, and infection is due to a predisposition of the tissues of the larch. The fungus on the larch always appears secondarily. The author observes that he found in the Obersteiermark a large heap of larch branches, lying there for years, and which, through the weight of the snow of many winters, had been much compressed. In disturbing the heap he found in the middle of it very large fruits of the fungus on the dead twigs. The moist air favoured the growth of the fungus considerably, and therefore the fungus comes into near relation to a saprophyte. . . ." I can confirm this observation, having often found in forests small dead twigs of larches on the ground, with the fruits of the fungus on them, but none on the trees. H. Marshall Ward, in his book, "Diseases in Plants," 1901, p. 152, refers to the necessity of certain conditions being present in a larch to favour an attack with the larch fungus, saying: " . . . Now the larch canker is also to be found on trees in their Alpine home, but there it does very little damage, and never becomes epidemic except in certain sheltered regions near lakes and other damp situations. . . . In its mountain home the larch loses its leaves in September, and remains quiescent through the intensely cold winter until May. Then comes the short spring and the rapid passage to summer, and the larch buds open with remarkable celerity, when they do begin, *i.e.*, when the roots are thoroughly awakened to activity. Hence the tender period of young foliage is reduced to a minimum, and any agency which can only injure the young leaves and shoots in the tender stage must do their work in a few days or the opportunity is gone, and the tree passes forthwith into the summer state. . . . In the plains, on the contrary, the larch begins to open at varying dates from March to May, and during the tardy spring encounters all kinds of vicissitu in the way of frost and cold winds, following on warm d which has started the root action. . . . It amounts to th therefore, that in plains, the long continued period of foliation allows insects, frost, winds, etc., some six weeks or two months in which to injure the slowly sprouting tender shoots; whereas in the mountain heights they have only a fortnight or so in which to do such damage." . . .

The late Prof. Hartig has observed the same peculiarity of other fungi. He relates that an infection of pines with *Chrysomyxa abietis*, the pine leaf rust, depends upon the degree of the development which the buds have attained at the time the sporidia of the fungus are distributed. One finds in the middle of May, in every pine plantation, trees with young shoots, besides those which only show just swelling. If the fungus distributes its spores already in the begining of May, only these pines will be infected which have already developed young shoots, whilst later sprouting trees will remain immune.

Speaking of *Caeoma pinitorquum*, the same author observes that in wet years, in which the tissues of the pines are rich in water, the new shoots of the pines are generally killed by the fungus, whilst in dry years the mycelium in the branches develops only slowly, and the shoots consequently remain healthy.

From these various examples, we come to the conclusion:—

(1) That one and the same fungus may live sometimes as a parasite and sometimes as a saprophyte;

(2) That fungi need for their development into a severe epidemic certain tendencies within a plant favourable to their growth;

(3) That our attention should be directed not only to learn the life history of a fungus, and the methods of locally combatting diseases, but especially to the investigation and study of the factors which predispose a plant to take disease;

(4) That quick and luxuriant growth in a plant indicates health, and that the restoration of normal conditions, after a period of abnormal growth, is enough to successfully prevent a severe attack by a fungus.

In conclusion, I must refer to our present methods of combatting diseases of plants. Dr Maudsley says, in his excellent paper referred to above: "Think for a moment of what happened when medicine blindly attacked symptoms at first sight." Let us recall the damage brought about by using fungicides to combat fungus diseases. Often the attack seems checked, when after a while the disease, with increased severity, rapidly kills even plants which had been sprayed for the sake of prevention only. Is it likely that a repeated spraying of the apple trees in the nursery attacked by *Fusicladium* would effectually have eradicated the disease? Or a like treatment of the vines, the larches, etc.? Is it not plainly shown that a plant grown in good soil, pure air, and other suitable conditions takes no disease, even though constantly surrounded by all kinds of dangerous germs? And on the other hand it recovers from an attack, when conditions have set in favourably to the growth of fungi, as soon as natural and healthy conditions have been restored? Should we, therefore, in phytopathology not establish as a principal condition the hypothesis—"*Keep, preserve, and restore the natural conditions under which the maintenance of health in a plant is assured, prevent all unnatural conditions predisposing them to take disease, and the success of such profilaxis will manifest itself in the decrease of plant diseases.*"

When will plant pathologists learn the lesson that the medical profession has now slowly, but surely learnt, in regard to Tuberculosis? This would be the first step forward from the science of phytopathology to the art of plant hygiene.